Contracting Office Address

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Description

Spacecraft Bus and Operations Request for Information (RFI) for the Climate Absolute Radiance and Refractivity Observatory (CLARREO) Mission

1. Introduction

The National Aeronautics and Space Administration (NASA) is conducting a mission formulation study for the CLARREO mission. CLARREO is a climate focused mission that will become a key element of the climate observing system. The foundation for CLARREO is the ability to produce irrefutable climate change records through the novel application of onboard traceability and calibration techniques. CLARREO will measure spectral reflected solar energy, emitted infrared radiances and Global Navigation Satellite System (GNSS) Radio Occultation (RO) refractivities. These measurements will be used to detect climate change trends and test, validate, and improve climate prediction models. The CLARREO mission will provide accurate, credible, and tested climate change records that lay the groundwork for informed decisions on mitigation and adaptation policies that address the effects of climate change on society.

Further information is available at the following websites (Note: the data found within this RFI is the most current data):

http://clarreo.larc.nasa.gov/docs/Decadal_Survey.pdf

http://clarreo.larc.nasa.gov/docs/CLARREO_Data_from_Decadal_Survey.pdf

http://www.star.nesdis.noaa.gov/star/documents/ASIC3-071218-webversfinal.pdf

This RFI including (referenced tables and figures) is posted at the CLARREO website: http://clarreo.larc.nasa.gov

The purpose of this RFI is to obtain information to support a Mission Concept Review (MCR) in late 2009 and to investigate options for procuring two spacecraft buses and spacecraft bus operations for the CLARREO mission. Each integrated spacecraft bus and Government Furnished Equipment (GFE) payload will form an observatory. A description of spacecraft bus development (1) and spacecraft bus operations (2) is captured below:

(1) Spacecraft bus development includes:
Spacecraft bus design, development and test, integration of GFE payload, full observatory functional testing, performance and environmental testing, shipment

to the launch site, support of launch operations, and on-orbit performance verification.

(2) Spacecraft bus operations include:
On-orbit spacecraft bus command and control; including the design, development, procurement, integration, testing, operational staffing, training, implementation and maintenance to provide spacecraft bus health and attitude control.

The submission of responses for either spacecraft bus development, spacecraft bus operations, or both, is acceptable. Vendors are not required to respond to both sections of this RFI.

This RFI seeks input from vendors with experience and facilities for designing, fabricating, and integrating Earth orbiting observatories. The following capabilities are deemed critical:

- Spacecraft bus management/development
- Subcontract management
- Quality management
- Safety management
- Systems Engineering
- Spacecraft bus fabrication and test
- Interface and Interface Control Document (ICD) development
- Payload integration and test support
- Observatory functional and environmental testing
- Coordination of observatory shipment to the launch site
- Launch vehicle integration support
- Launch and early orbit checkout operations
- On-orbit operation
- Sustaining engineering
- Flight software maintenance

Responses to this RFI shall be commensurate with the requirements for the CLARREO mission described below.

The CLARREO mission is currently envisioned to consist of two duplicate observatories each carrying a payload of one infrared (IR) instrument suite, one reflected solar instrument suite and a GNSS RO instrument system. The IR instrument will be pointed with respect to the spacecraft bus nadir deck by an instrument internal mirror to enable nadir, off-nadir, internal calibration, and deep-space (zenith) observations. The reflected solar instrument suite consists of three spectrometers which will be co-boresighted, combined into a single instrument suite and mounted to a two-axis gimbal to enable nadir (nominal operations), and off-nadir Lunar and Solar observations. The two-axis gimbal is assumed to be part of the payload. The GNSS-RO will require a total of three antennas integrated on the ram, wake, and zenith faces. The zenith face antenna will be a precision orbit determination (POD) antenna. The GNSS RO system is considered a science instrument; the spacecraft bus should provide an independent means for acquiring any required observatory position information. The instruments are currently envisioned to be integrated on a payload structure and then integrated as a payload assembly to the spacecraft bus. The only exception is the GNSS wake antenna which will need to be integrated to the spacecraft bus (See Figure 2). The payload instruments, related hardware, and software elements shall be considered to be provided by others.

Two possible observatory / launch vehicle configurations are currently envisioned and are being evaluated:

- Configuration A: The first configuration is a dual manifested launch with both observatories and a preliminary Launch Readiness Date (LRD) of December 2016.
- Configuration B: The second configuration consists of two separate observatory launches. The preliminary LRD for the first observatory is July 2016, and the preliminary LRD for the second observatory is January 2017.

The unique requirements for the CLARREO spacecraft buses are as follows:

2. Mission Requirements (Both Observatories)

- Minimum Operational life: 3 years with consumables for 5 years
- Nominal Orbit Altitude: 600 kilometers
- Nominal Orientation: Local Vertical Local Horizontal (LVLH)
- Orbit: Earth orbiting, 90 degree polar inclination, 90 degree separation in longitude of the ascending node between observatories (when looking down at the North pole, the two orbit planes are separated by 90 degrees)
- Payload risk classification of "C" should be assumed per NASA Procedural Requirement (NPR) 8705.4 Risk Classification for NASA Payloads
- Yaw flip maneuver required 2 times per year for payload thermal management
- Spacecraft bus must be capable of automated fault detection and protection (failure, detection, isolation, and recovery capabilities)
- Spacecraft bus must be capable of reprogramming the on-board flight software to adjust for mission needs and address anomalies
- Spacecraft bus must meet the NASA Procedural Requirements for Limiting Orbital Debris (NPR 8715.6A) and NASA Process for Limiting Orbital Debris (NASA-STD-8719.14)
- Contamination Requirements
    - Non-metallic materials shall be limited to a Total Mass Loss (TML) < 1%
    - Non-metallic materials shall be limited to a Collected Volatile Condensable Mass (CVCM) < 0.10%
    - Although values have not been determined, spacecraft bus will need to meet a specific outgassing rate, including solar array(s)
    - Although values have not been determined, the spacecraft bus will need to meet, lower than typical, specific deliverable and End of Life

(EOL) particle levels identified in Product Cleanliness Levels and Contamination Control Program (IEST-STD-1246)
  - Observatory integration and test operations shall be conducted, most likely, in a 10K (ISO Class 7) clean room
  - Spacecraft bus venting shall be preferentially directed orthogonal to the ram / wake direction.

3. Payload Description (All mass and power numbers reflect Current Best Estimate (CBE) plus contingency)

- Total Average Payload Power 418 Watts (334 CBE plus 25% contingency)
- Total Payload Mass 339 kilograms (271 CBE plus 25% contingency)
- Payload shall not use spacecraft bus for thermal energy dissipation (adiabatic payload/spacecraft bus interface)
- MIL-STD-1553B command and telemetry bus to payload instruments can be assumed
- Serial data interfaces sufficient to support the science data rates should be assumed

Instrument descriptions are shown in Table 1. All mass and power numbers reflect Current Best Estimate (CBE) plus contingency

Table 1. Payload Characteristics

GNSS RO and antennas	
Instrument characteristics	
Mass	17.5kg (14 CBE + 25% contingency)
Average Power	40W (32 CBE + 25% contingency)
Data Rate to SSR	50 kbps
Date Volume	648 MB/day (540 MB/day + 20% for Reed-Solomon & CCSDS)
Receiver physical size	10 x 20 x 10 cm
Antennas	Mounted on spacecraft ram, wake and zenith panels. The ram and wake face antenna size is 50 x 25 x 2 cm and the zenith face (POD) antenna size is 5 x 5 x 10 cm.
Unobstructed Field of Regard (FOR)	See Figures 3 and 4 for ram, wake and zenith FOR

Infrared Instrument and Electronics	
Instrument characteristics	
Cryocooler	77 degree Kelvin cryocooler
Mass	96 kg (77 CBE + 25% contingency)
Average Power	186 W (149 CBE + 25% contingency)
Data Rate to SSR	950 kbps
Date Volume	12.31 GB/day (10.26 GB/day + 20% for Reed-Solomon & CCSDS)
Instrument physical size	45 x 69 x 75 cm
Unobstructed Field of Regard (FOR)	(+/-) 5 degrees off Nadir. (+/-) 45 degrees off zenith (See Figures 3 and 4)

Reflected Solar Instrument Suite (3 Spectrometers and electronics)	
Instrument characteristics	
Mass	99 kg (79 CBE + 25% contingency)
Average Power	118 W (94 CBE + 25% contingency)
Data Rate to SSR (Nominal)	3.82 Mbps
Date Volume (Nominal)	49.51 GB/day (41.26 GB/day + 20% for Reed-Solomon & CCSDS)
Data Rate to SSR (Peak)	240 Mbps (once per week for a 250 second calibration)
Data Volume (Peak)	58.51 GB/day (once per week) (48.76 GB/day + 20% for Reed-Solomon & CCSDS)
Instrument physical size	20 x 25 x 30 cm (per spectrometer)
Unobstructed Field of Regard (FOR)	(See Figures 3 and 4)

Reflected Solar Instrument Gimbal and electronics	
Characteristics	
Mass	66 kg (53 CBE + 25% contingency)
Average Power	24 W (19 CBE + 25% contingency

Payload Mounting Structure and Payload Controller	
Characteristics	
Mass	61 kg (49 CBE + 25% contingency)
Average Power	50 W (40 CBE + 25% contingency)

4. Communications and Data Handling:

- Science data communication: X band at rates compatible with NASA Ground Network in a Consultative Committee for Space Data Systems (CCSDS) standard format
- Command and spacecraft bus telemetry communication: S band at rates compatible with the NASA Ground Network in a CCSDS standard format
- Reliable CCSDS File Delivery Protocol (CFDP) Level 2 support
- Spacecraft bus will downlink both X and S-Band with ground stations 6-9 times per day
- NASA Near Earth Network (NEN) will be utilized for nominal, on-orbit spacecraft commanding and data reception (ground stations will include: Poker Flats, AK; Wallops Island, VA; and Svalbard, Norway)
- NASA Space Network (TDRSS) will be utilized for launch and early orbit and contingency commanding.
- Connectivity with NEN and TDRSS ground stations will be accomplished via the NASA Integrated Services Network (NISN)
- Data Storage: Solid State Recorder of sufficient size to meet science data volume, expected downlink schedule, and recommended margin.

5. Attitude Determination and Control System

- Spacecraft bus to maintain Local Vertical Local Horizontal (LVLH) attitude throughout the mission duration.
- 2 yaw flip maneuvers per year required for payload thermal management
- 3-axis stabilization
- Attitude knowledge: < 0.1 degree or 360 arc seconds
- Attitude accuracy: < 0.1 degree or 360 arc seconds
- Attitude jitter: < 0.01 degree or 36 arc seconds
- Attitude drift: < 0.01 degrees or 36 arc seconds over 0.1 seconds

6. Propulsion

- Spacecraft bus must carry on-board propulsion system to account for launch injection dispersion, orbit maintenance up to 5 years within +/- 200 meters altitude and +/- 0.1 degrees inclination, momentum dumping and deorbit requirements.
- Spacecraft bus must meet the NASA Procedural Requirements for Limiting Orbital Debris (NPR 8715.6A) and NASA Process for Limiting Orbital Debris (NASA-STD-8719.14). Please assume a controlled re-entry is necessary and include this in the spacecraft bus propulsion system sizing.
- For the dual manifest launch configuration, assume the launch vehicle inserts one observatory at an inclination of 90.97 degrees and the second observatory at an inclination of 89.03 degrees. Both observatories drift for approximately one year and then assume each observatory performs a propulsive maneuver

to an inclination angle of 90 degrees so that both observatories are at 90 degree inclination with 90 degree separation in longitude of the ascending node between observatories. The estimated delta V for this propulsive maneuver is approximately 128 m/s for each observatory and should be included in the spacecraft bus propulsion system sizing. This propulsive maneuver is not required for the separate launch configuration.

7. Launch

- Configuration A: Dual manifest launch configuration:
    - For purposes of accommodation, please recommend a launch vehicle for the dual manifested launch in 2016
- Configuration B: Separate launch configuration:
    - For purposes of accommodation, please recommend a launch vehicle for the separate observatory launches in 2016 and 2017.
- In both configurations, assume the launch vehicle shall be a US launch vehicle and considered Government furnished.
- In selecting a launch vehicle, the vendor shall maintain a minimum mass margin of 30 % between the observatory mass (CBE + contingency) and the launch vehicle's lift capability to the CLARREO orbit.

8. Operations

- Although each observatory has an operational lifetime of 3 years with consumables for 5 years, CLARREO operations will be designed for a long-term mission (20 years or more) with replacement observatories. RFI responses shall consider the cost of annual operations and maintenance as well as the recurring cost to refresh the spacecraft operations hardware (approximately every 5 years).

    - The spacecraft operations system will be designed to minimize the cost and risk of operations, including minimizing the number of operators required to safely command and control the spacecraft, and maximizing use of spacecraft and ground system fault detection, reporting and protection tools.

- The CLARREO payload will be operated by other organizations separate from the spacecraft bus. Payload commands will be sent to the spacecraft bus via the spacecraft operations center. The spacecraft operations center will verify payload commands in order to ensure the safety of the bus, otherwise payload operations are beyond the scope of this RFI.

- The conceptual, on-orbit system architecture is shown in Figure 1. below:

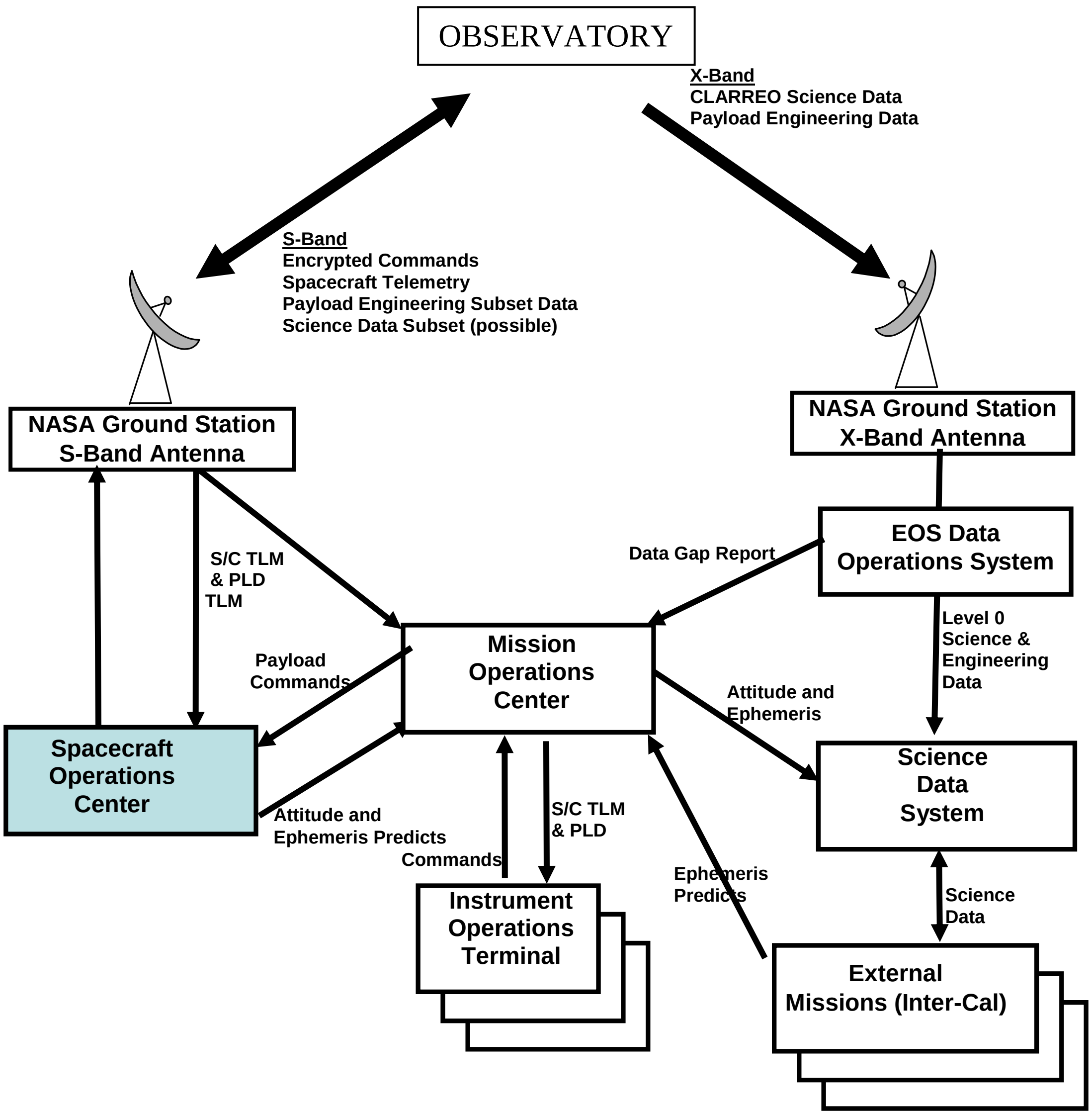

Figure1. Ground System Architecture

Spacecraft operations functions will include, but are not limited to:

- Command and control: The spacecraft operations center (OC) will plan and execute all commanding for both spacecraft and will verify and transmit all commanding for the instruments. The OC will plan and execute command uploads approximately once per day per observatory. Each observatory will likely require routine maneuvers in order to maintain proper orbit parameters and thermal control (2 yaw flips per year).

- Planning and scheduling: The OC will be able to perform all of the activities and functions required to maintain the health and attitude of both observatories; including planning all contacts with the observatory, integration of flight dynamics data, coordination/scheduling with the NASA Near Earth Network (and Space Network as required), and building, transmitting, and verifying command loads. The observatory will downlink with earth stations as discussed in Section 4: Communications and Data Handling above.

- Trending and analysis: The OC will have tools to automatically select, store, trend, display, and report spacecraft engineering data.

- Anomaly resolution: The OC will be capable of quickly responding to and correcting anomalies with either the observatories or the ground system.

- Flight dynamics: The OC will be capable of generating flight dynamic products from onboard GPS data and ground network tracking data. The response to the RFI should indicate if the OC will need to interface with and utilize products from external sources during launch and early orbit or contingency response (such as the Flight Dynamics Facility (FDF) at Goddard Space Flight Center).

- On-board data storage management: The OC will be capable of tracking and managing the storage space for science data onboard the observatory.

- Integration and testing: The OC and mission ops team will support integration and testing of the payload and the spacecraft bus. The OC software and tools will be utilized for spacecraft I&T.

- Mission simulations: The OC will utilize mission simulations and spacecraft/instrument simulators in order to verify command uploads and to support training of operational personnel.

GUIDE FOR RFI RESPONSES

VENDOR PROPOSAL CONTENT INSTRUCTIONS

Responses to this RFI will support a Mission Concept Review (MCR) preliminarily scheduled for late 2009. Please provide information on the spacecraft bus that meets the above requirements and accommodates the payload. The requested information is documented in the following sections.

Spacecraft Bus Development:

Section 1- Description of proposed spacecraft bus including spacecraft configuration, hardware capabilities, redundancies, payload accommodation, accommodation in launch vehicle, deployments, fields of view description, alignments and calibration, attitude control methodology, command and data flow. Please include discussion and presentation on accommodation of the payload and fields of view. Payload CAD models (in STEP (.STP) format) providing notional representations of the payload will be provided upon request.

Section 2 – Description of the reliability of the proposed bus including: all margins and redundancies, fault detection and protection, potential risks and mitigations, any new designs and associated risks. In addition, please identify any payload requirements that contribute to the spacecraft bus design and development risks.

Section 3 – Identification of requirements that are drivers for spacecraft bus and accommodation in the launch vehicle. Please suggest changes in requirements that will result in substantial cost reductions. In addition, suggest accommodation approaches that will meet the requirements but would require changes in the payload design.

Section 4 – Description of the proposed spacecraft bus heritage. If the proposed bus is substantially different from a heritage bus, then propose suggestions in payload design or payload requirements that would enable use of a heritage bus.

Section 5- Description of the observatory mass and power breakdowns by subsystem. Include the current best estimate (CBE) for mass and power and recommended contingencies for each subsystem. Any additional margins in the spacecraft bus design beyond the stated contingencies should be identified. The payload mass and power numbers in this RFI are current best estimates with contingency included. In selecting a launch vehicle the vendor shall maintain a minimum mass margin of 30% between the observatory mass (CBE + contingency) and the launch vehicle's lift capability to the CLARREO orbit.

Section 6 – Description of the assembly, integration, test and launch operations approach for the spacecraft bus and observatory levels. Any differences from the contractors normal test flow should be identified and described.

Section 7- ROM price estimates, including required funding profile, and schedule, including reserves for: spacecraft buses and full mission observatory implementation consistent with the above characteristics and capabilities (including spacecraft bus management/development, subcontract management, quality management, safety management, systems engineering, spacecraft bus fabrication and test, interface and ICD development, payload integration and test support, observatory functional and environmental testing, coordination of observatory shipment to the launch site, launch vehicle integration support, on-orbit checkout, sustaining engineering, and deliverable documentation).

Section 8- Description of key technical, schedule and price drivers and options to mitigate and/or trade against price reductions.

- Information on technical, schedule and price drivers associated with developing two spacecraft buses for both launch configurations (A and B) is of interest. Please describe the optimum spacecraft bus development approach for both launch scenarios.

- Given that the CLARREO mission is envisioned to be a long term mission (20 years or more), information on developing a spacecraft bus where costs savings can be realized based on multiple units being built and procured, including the option of adjusting the spacecraft bus lifetime and subsequent launch spacing is of interest. Cost differences between the 1^{st} and 2^{nd} unit as well as between the 2^{nd} and 3^{rd} units for follow on missions is desired.

Section 9 - ROM price estimate and description of a spacecraft bus interface emulator to be used to test interfaces with the payload/instruments. Current plans include test and verification of the power and data hardware and protocol interfaces between the spacecraft bus and payload/instruments before system level integration and test activities.

<u>Spacecraft Operations:</u>

Section 10- Description of spacecraft operations to include:

- The recommended choice of operational software tools (indicate if these are COTS/GOTS/or mission specific), operations center hardware, and simulators.

- The staffing required for development and operations, the phasing of required manpower, and the level, description, timing of operational training.

- The level and descriptions of autonomous flight operations.

- Maintenance concepts for operations center software and hardware, with an emphasis on supporting a long-term mission.

- Mission unique test provisions.

- Flight Software Maintenance

- Diagrams of data flow and operational processes.

Section 11- ROM price estimates, including required funding profile, and schedule for operations center design, development, procurement, integration, testing, staffing, training, implementation, and maintenance. Include recommended contract types and options (e.g., fixed price versus cost, options for hardware refresh)

Section 12- Description of key technical, schedule and price drivers and options to mitigate and/or trade against price reductions. Please suggest changes in requirements or concepts that will result in substantial cost reductions.

- Information on technical, schedule and price drivers associated with developing a spacecraft operations capability for both launch configurations (A and B) is of interest.

- Information on technical, schedule and price drivers for designing, implementing, staffing, and maintaining a highly automated operations center is of interest.

<u>Vendor Capabilities:</u>

Section 13- Description of company capabilities and past experience performing spacecraft bus management/development, observatory I&T, launch support, and mission operations similar to this mission

Figures 2-4 show multiple views of the CLARREO observatory and the FOR requirements.

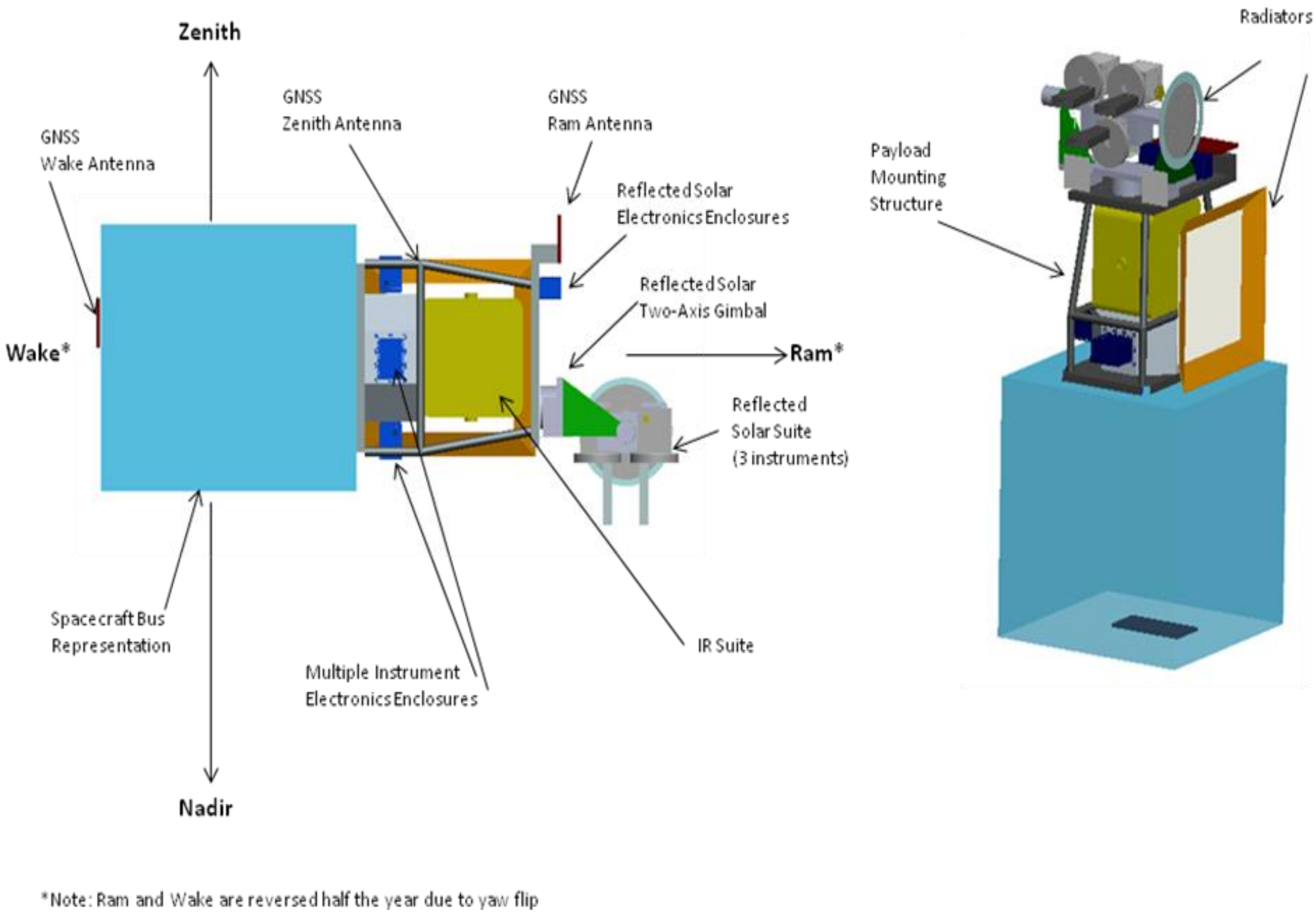

Figure 2. CLARREO Payload Description (side and iso view)

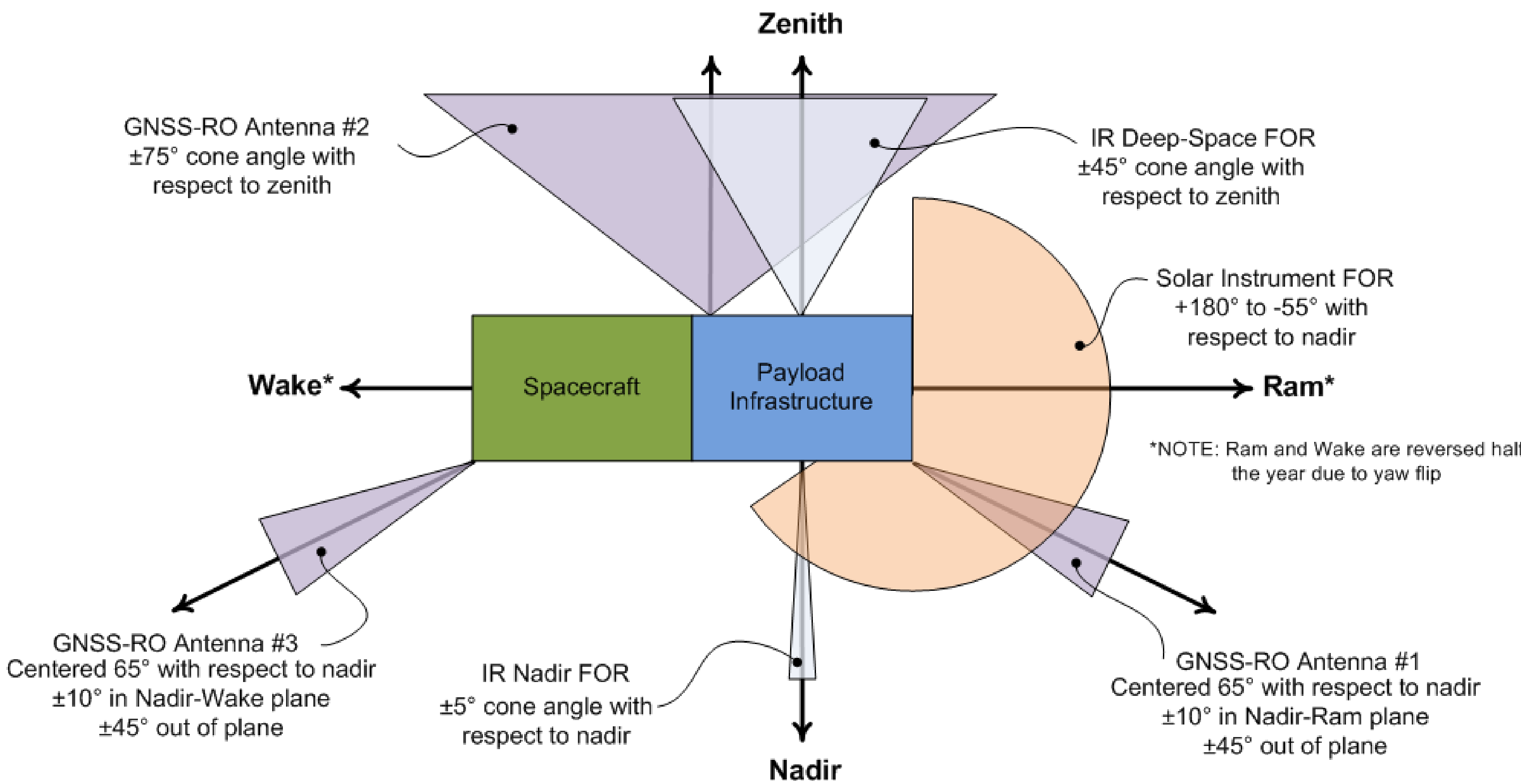

Figure 3. CLARREO Payload Field of Regard Requirements (side view)

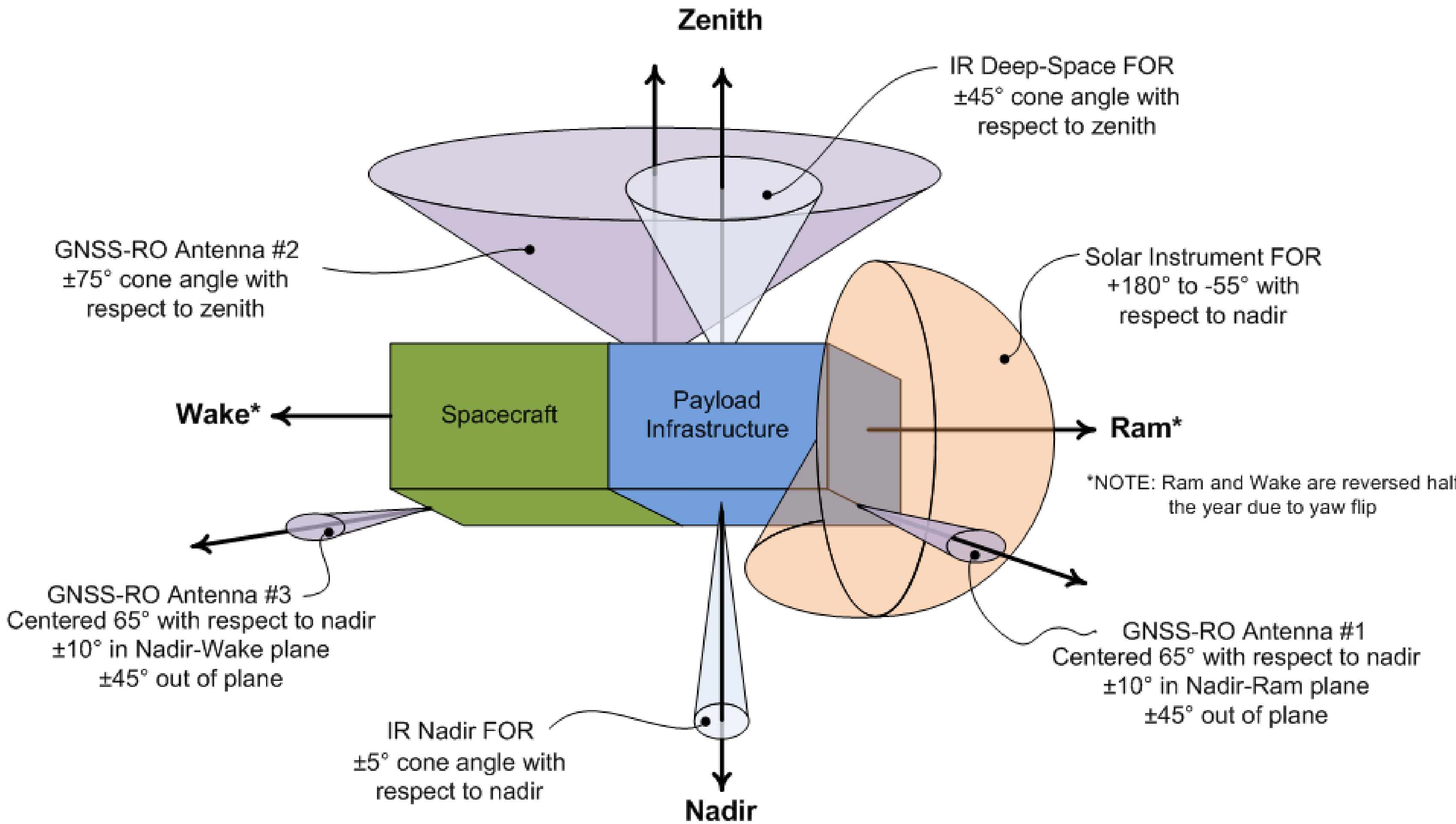

Figure 4. CLARREO Payload Field of Regard Requirements (iso view)